Maglehøj – preservation of birch bark in a passage grave with evidence of forced entry in prehistory

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ABSTRACT

Maglehøj is a Danish passage grave which has birch bark incorporated into its construction. An account of the opening of the monument in 1823 reports the discovery of an earth-free chamber and describes constructional details, including the use of birch bark. An investigation undertaken in 1996, prompted by the information given in this account, revealed that the birch bark was relatively well preserved and that there had been a break-in through one gable of the chamber later in prehistory. This article gives several examples of similar intrusions, which were a more common phenomenon than previously appreciated. The results of the climatic conditions inside Maglehøj's chamber, aimed at optimising preservation of the birch bark, are also presented. The investigation included measurements of air change and humidity carried out under different conditions. The outcome was a recommendation that the entrance to the chamber be closed with an air-tight seal.

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Introduction

Of the many passage grave chambers that, especially in the 18th and 19th centuries, were opened for the first time since prehistory, some were found to be empty of earth, precisely as when they were used and then closed for a final time more than 4000 years ago. Numerous megalithic tombs have been opened in modern times some by farmers and stone masons, others by the landed gentry, clergymen and others with an interest in the past. A few descriptions exist of how these earth-free chambers appeared and were laid out when they were entered. This was, as a rule, through the roof or through the stone layer between the orthostats and capstones. Probably the most detailed and comprehensive account of such an entry into an earth-free passage grave chamber relates to Maglehøj on Stevns, southeastern Zealand. Moreover, out of a total of 14 passage graves where birch bark is present, Maglehøj is the tomb in which the bark is best preserved. An investigation undertaken in 1996 had aims which included clarification of the preservation criteria for the birch bark. This investigation was followed up between 2013 and 2018 by an investigation of the climatic conditions in the chamber directed at establishing optimal conditions for preservation of the bark.

The opening of the passage grave in 1823

The passage grave was opened by the user of the plot of land on which the monument stood, smallholder Lars Rosted, who began to dig away at the mound in April 1823 to gain new cultivable land. In the process, he struck a burial chamber which the vicar in the nearby village of Hellested, Peter Holm (1766-1831), immediately became aware of and was greatly interested in. He followed the work of exposing and entering the chamber, and he submitted two accounts to *Den kongelige Commission til Oldsagers Opbevaring* (i.e. the Antiquities Commission). This was set up in 1807 and its aims included acting to preserve prehistoric monuments. Already in his first report to the commission, Pastor Holm mentions that the chamber in Maglehøj resembled that in Julianehøj near Jægers-

pris, which was excavated in 1776 (report of 24 April 1823 in the archive of the Danish Agency for Culture and Palaces).

The Antiquities Commission addressed Pastor Holm's first letter at its meeting on 16 May 1823 (Jakobsen 2007, 279) and in their letter of reply included a request to Count Moltke to schedule (i.e. protect) the monument. Lars Rosted continued exposure of the passage grave under Pastor Holm's supervision, and in his next report Pastor Holm gave a thorough description of both the passage grave's earth-free interior and of the monument's construction outside the chamber (report of 16 May 1823). Other contemporary accounts about the opening of passage graves focus especially on the artefact inventory and the skeletal material. What makes Pastor Holm's description unusual and significant is his archaeological observations of the monument's layout and construction. Maglehøj's contents were, however, very modest in comparison to other passage graves.

Together with his report about the opening of Maglehøj, Pastor Holm also submitted the artefacts that had been found. These were incorporated into *Det Kongelige Museum for de Nordiske Oldsager* (i.e. the Royal Museum of Antiquities) with the accession numbers DCCCLXXXVI-DCCCXCIV (i.e. 886-894). The artefacts comprised two flint axes, two flint daggers, six roughouts for arrowheads, some potsherds, samples of birch bark, samples of the white coating on the orthostats and of the reddish soil by the skeletons. Finally, there were also parts of three skulls and some human bones (Thomsen and Thorlacius 1827, 260-262).

Pastor Holm's reports about Maglehøj did not leave their mark in the later archaeological literature – with one notable exception: V. Boye refers to Maglehøj in a note: 'As in Maglehøj in Hellested parish (Stevns hundred, Præstø county), where birch bark was packed between the slabs that filled out the gaps between the chamber's orthostats' (Boye 1862, 339). It was established in 1995 that the birch bark in Maglehøj was still in a relatively intact state. The only other known occurrence of birch bark in a passage grave at that time was in Jordhøj near Mariager, where it was found by V. Boye on opening this monument in 1890 (Dehn and Hansen 2006, 29-31). The rediscovery of relatively well-preserved birch bark in Maglehøj prompted efforts to ensure its optimal preservation. An investigation of the monument was therefore launched in 1996, and Pastor Holm's description of the opening of the passage grave again acquired relevance.

Pastor Holm's report to the Antiquities Commission

It is evident from Pastor Holm's report that smallholder Lars Rosted had dug on the spot for some time 'to gain arable land', before the clergyman heard of the activity. Pastor Holm was, however, apparently given an account of what had happened prior to his involvement. The digging began at the edge of the mound, where skeletons were encountered. Rosted also struck kerbstones and therefore presumed that there could be a 'place of burial' in the mound, so he began to dig in the top of the mound. Here, too, he found skeletons – some of them in 'a stone-built box'. It was first below this that he encountered one of the chamber's capstones and by removing a smaller stone, he was able to look directly into the earth-free chamber. Here, he saw bones lying on a floor covered with small round stones.

Pastor Holm then gives an account of what happened in April in connection with Lars Rosted's digging in the top of the mound and opening of the chamber through the roof:

At a depth of more than 3 alen [1.9 m]*, he encountered stones and found there, in a box built of small stones, approximately 3 quarter* [0.5 m] *square, a skull that on the least contact crumbled away; otherwise, there was only earth in the box. Immediately below this he encountered a very large boulder beside which a smaller flat stone was taken up, whereby there came an opening into the grave chamber from above, through which opening he clearly enough could glimpse the white human bones and the neat, smooth stone layer of small round beach pebbles, on which the bones lay.*

When Rosted entered the chamber, he gathered the best-preserved bones, while others crumbled completely at the slightest touch. He took the intact bones out from the chamber and buried them in a sand pit in the vicinity. He also found two

flint daggers and an empty pottery vessel in the dry sand of the chamber floor, but the pot disintegrated completely. He then dug through the floor with a spade but found no further artefacts.

When Pastor Holm himself gained access to the chamber, he described it as follows:

In between these dry-walling slabs a kind of bark has been placed, of which follows a small sample in no. 1. The man who has excavated the mound says that it is birch bark, which he, as a Norwegian, professes to know well. Around by the sides of this wall was a fine, white material of which follows a sample no. 2; presumably it is saltpetre or lime.

Pastor Holm further explains that there has been a platform in the middle of the floor bearing the remains of the individuals interred here – raised above the rest of the floor and apparently with a kerb of stones placed on edge:

Within this oval room is another oval, 4 alen and 3 quarter [3 m] long and in the middle almost 2 alen [1.3 m] wide, but like the form of the outer broader in the southeastern and narrower in the northwestern end. The floor in this room is a good quarter [15.7 cm] *higher than the floor in the rest of the burial chamber, laid with beach pebbles, surrounded by roundish, not very large boulders, which stand up a few inches* [of 2.5 cm] *above the floor.*

Pastor Holm argues that there must have been a break-in uppermost in one of the gables:

There are major grounds to presume that the grave in the earliest times has been opened and plundered; because when Rosted first entered the burial chamber, he found at the southeastern end loose, blackish topsoil that had slipped down from above, as there was otherwise in the grave only sand and stones, on which the corpses, without any form of covering or clothing were placed. Furthermore, the wall or stone wall was not constructed of slabs, which is why the earth has slipped, as otherwise around and between the upright stones, but simply covered with a couple of large slabs set on edge with their surface in towards the grave. This less sealed walling-up has caused a limited degree of damp in the burial chamber at the southeastern end, where the stones are covered with saltpetre, which is not to be found in the northwestern end. Finally, the mound has externally in places been less rounded and somewhat indented directly over this place where the opening can be traced.

Pastor Holm describes the original closure of the passage, as seen described for other passage graves, that is a flat stone as a door, sealed from the outside with stones:

The outermost part of the entrance passage was covered or packed with quite large boulders of varying form; within these directly by the opening was a fine, flat stone erected.

The outer part of the passage, presumably outside the door slab, was damp:

The earth here was damp and very compact, and the bones brittle and fragile, although the teeth in one jawbone were particularly fresh and still shiny. Of a kind of reddish soil, of which there was only a little here, follows a sample no. 3, as this appeared to be heavier than ordinary soil or clay. The bones lay in bare earth, without sand; it was difficult to extract them from the compact soil.

The inner part of the passage was dry:

The inner part of the passage was dry, filled with small stones, earth and bones; but nothing else was found. In the outer part of the passage, I discovered charcoal yesterday, but only a few small speckles.

Pastor Holm also describes the stratigraphy above the capstones, presumably as he observed it in Lars Rosted's excavation in the top of the mound. The stratigraphy corresponds fully to modern observations – he did not, however, see that the stone slabs were probably overlapping:

It is remarkable the care with which efforts have been made to ensure that the burial place is preserved from the penetration of water and damp. Immediately on top of the capstones a layer of flint has been laid approximately 1 quarter [15.7 cm] *in thickness; on top of this a layer of white clay or lime marl of the same thickness; over this again a layer of red clay of the same thickness; on top of this stone slabs, and then again a layer of red clay also approximately 1 quarter thick, and on top of this ordinary topsoil to the roof of the mound.*

Pastor Holm estimates the height of the mound to be just less than 6.3 m; today it is 4-5 m high. This concurs roughly with Lars Rosted first encountering the capstones 1.9 m below the surface. Together with skeletal remains found outside the chamber, this indicates that the megalithic mound had been extended with at least one mound phase; a relatively common occurrence. It is also possible that there has been a Bronze Age mound outermost:

Figure 1. During the investigation at Maglehøj in 1996, five dry-walling slabs with preserved birch bark in between were extracted and fixed as a block for museum storage (Photo: T. Dehn).

The entire mound is constructed on a level bank that, despite its height has not been large and hardly 10 alen [6.3 m] *from the base of the burial chamber, has made it appear more conspicuous than if it had been placed on lower ground.*

The investigation of Maglehøj in 1996

The investigation of Maglehøj in 1996 was planned based on information contained in Pastor Holm's reports of 1823. Its aims were:

1) to record the birch bark in the passage grave's dry-walling,
2) to extract a block sample containing birch bark in collaboration with the National Museum of Denmark for storage in the museum's storage facilities (Figure 1),
3) to attempt to establish the significance of the monument's construction for the preservation of the bark and
4) to attempt to find an explanation for the unusual construction of one gable of the chamber which, on the face of it, resembled a modern restoration.

In addition to recording the birch bark that was immediately visible from inside the chamber, a 2-m-wide excavation trench was dug into the mound by the southeast gable, where the birch bark is chiefly found and where some of the mound has already been removed, presumably by Lars Rosted in 1823. This trench exposed the rear of the chamber's gable, together with the construction of the mound, with its packing of crushed flint and clay (Figure 2 and 3). It was also possible here to remove a block sample containing four dry-walling slabs and the folded birch bark between them. It also became apparent that parts of the original construction of both the overlying mound and the chamber had been disturbed and then re-established following a break-in uppermost in the chamber's gable later in prehistory. Given that flint daggers were found in the chamber in 1823, it seems likely that this intrusion took place in Late Neolithic times (*c*.2350-1700 BC).

The birch bark in Maglehøj is dated to 4440 ± 50 (KA 6975), calibrated (Stuiver et al. 1998) ± 1 st. dev.: 3330-2920 BC (Dehn and Hansen 2006, 26). This dating is consistent with the dating of seven other passage graves with birch bark, whose dating is within the period 3350-2850 BC (Paulsson 2010, 1010-1012).

Pastor Holm's observations and the 1996 investigation

Pastor Holm's observations, combined with the results of the investigation in 1996, give a valuable picture of the layout and construction of the Maglehøj passage grave. It is intriguing that no traces whatever have been recorded today of the mound's latest phase. Already when digging at the edge of the mound, Lars Rosted encountered skeletons. It must be presumed that these originate from graves outside the original passage grave mound, because it is apparent that the mound has been almost 2 m higher than today and must, thereby, have had a significantly greater diameter than now.

In conjunction with the skeletons at the edge of the monument, Lars Rosted also found a ring

Figure 2. Maglehøj 1996. Section showing the intact construction of the mound outside the southwestern end of the chamber. Immediately adjacent to the orthostat and intermediary layer lies a packing of crushed flint, held in place by a structure of stones and mound fill. It is evident that the latter was added in three operations (1-3) (Drawing: T. Dehn, L. Holten and M. Nissen).

Figure 3. The excavation trench at Maglehøj in 1996 and the southwestern gable of the chamber. The area below the yellow line is the intact structure of the passage grave. The area above the line was altered later in prehistory, probably during the Late Neolithic (Photo and drawing: T. Dehn).

of kerbstones and he presumed that there could be more graves farther in. He therefore began to dig in the top of the mound and found skeletons of several individuals here, too. One of them lay in a stone-lined grave at a depth of about 2 m below the surface. The striking increase in the height of the passage grave mound could have taken place in both the Bronze Age and Iron Age. One example of massive expansion of a megalithic mound in the Bronze Age is provided by the passage grave at Sulkendrup Mølle, which was investigated in 1919 and underwent restoration in 2013-14. A stone-built Bronze Age grave was established above the passage grave chamber here, and the mound was extended so the passage of the passage grave lay 5 m within a new kerbstone ring (Rosenberg 1929, 206).[1] It is possible that there was further expansion later, as there were also Iron Age graves in the top of the mound.

Immediately beneath the Bronze Age grave in the top of Maglehøj, Lars Rosted encountered the upper surface of one of the chamber's capstones. He removed a smaller, flat stone at the edge of the latter and was then able to look directly down into the earth-free passage grave chamber.

Looking at the chamber from the inside today, there is only one place where it is possible to penetrate the roof without moving capstones, and this is between capstones 30 and 31 (Figure 4). Pastor Holm mentions in his first report of 24 April 1823 that the gap between the capstones is so narrow that he was only able to pass through with difficulty and without his outer garments. He then briefly describes the passage grave from inside. He notices

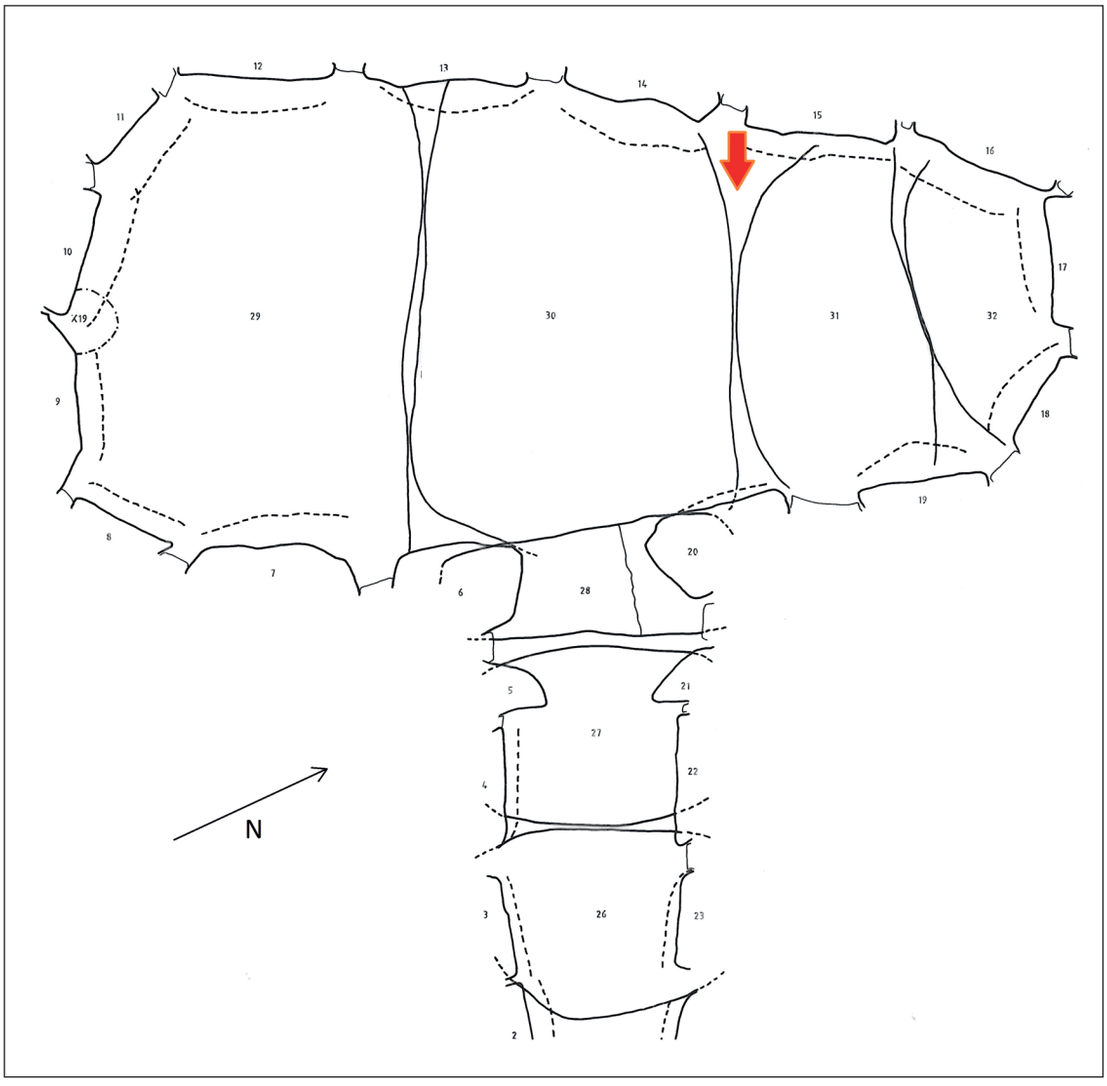

Figure 4. Ground plan of the Maglehøj passage grave. The red arrow marks where the chamber was entered between the capstones when the monument was opened in 1823. The chamber is 5.6 m long (Drawing: L. Holten and M. Nissen).

that the passage is blocked, so he asks Lars Rosted to empty it to provide easier access. From his second report of 16 May 1823, it is apparent that he has been in the chamber again but has now entered via the passage. This new description is extremely thorough and detailed and is presumably combined with what Lars Rosted has told him about his first visit to the chamber. Not only are the chamber's orthostats and dry-walling with birch bark precisely described, but also the floor, which, according to the first description, is said to have been dug up by Lars Rosted.

The chamber's ground plan is stated as being oval, but broader at the southeastern end. The chamber is 5.6 m long and 2.5 m wide in the middle. Within this oval room there is a 15-16 cm high raised platform on the floor, 3 m long and almost 1.3 m wide in the middle, and of the same oval form as the chamber's ground plan. This is laid with small, loose beach pebbles, and around the edge stand some 'roundish, not very large boulders', which extend 'a few inches' above the floor. Over the chamber are three large capstones and a lesser one. This arrangement of the chamber floor is quite unusual. Normally, chamber floors are covered to varying degrees by cobblestones or flagstones, to which can be added various examples with clay, sand and fire-shattered flint (Ebbesen 2011, 276-278). The situation on the chamber floor can vary considerably when initially described. It has often been disturbed in conjunction with the discovery of the passage grave and perhaps the first steps in

Figure 5. The southwestern gable of the chamber in Maglehøj seen from the inside. The flagstone set on edge associated with the secondary closure is the light stone in the upper left (Photo: T. Dehn).

demolition. Moreover, many passage graves have been reused and altered during later periods of prehistory and, in conjunction with this, several layers of graves have been laid one on top of the other. Intrusions and alterations have resulted in the chambers becoming gradually filled with settled and subsided mound fill. Only rarely is there information about the chamber being entirely earth-free when it was discovered and opened. But one of these instances is, of course, Maglehøj.

With reference to Lars Rosted's description, Pastor Holm then reports that the skeletons of four individuals – two adults and two children – lay on this platform. The skeletons were disarticulated, and the bones were mixed and scattered. Pastor Holm explains this in terms of the passage grave having been plundered already in prehistory. When Lars Rosted entered the chamber for the first time, he noticed a heap of black topsoil, which had fallen from above, at the southeastern end of the chamber. The materials were exclusively sand and stones in the remainder of the chamber, so this heap obviously stood out clearly. Pastor Holm notes that the construction of the chamber differs above the heap of topsoil in that the wall between the orthostats and the capstones is not constructed of horizontally laid slabs, as in the rest of the chamber, but merely closed with a couple of vertical flagstones (Figure 5). Due to a covering of saltpetre on the surface of the stones at this end of the chamber, Pastor Holm concludes that there has been some leakage here. His conclusion is supported by the surface of the mound here always having been less rounded and 'rather depressed'.

Pastor Holm's interpretation was fully confirmed during the investigation in 1996. The reverse of one of the vertical slabs between the orthostats and capstones was visible in the excavation trench which exposed the rear of one gable. It was clear that the mound construction in the part behind this slab was not the original. Instead of meticulous sealing with flint packing and clearly stratified mound fill, in this area there was unstructured fill containing topsoil mixed with stones of all sizes. This was interpreted as backfill in a large pit dug behind the uppermost part of the chamber's gable (Figure 6). In this backfilling, some of the material has penetrated the poorly sealed rebuilding of the gap between orthostats and capstones, where access was gained to the chamber, which is why Lars Rosted noticed a heap of soil here. Subsequent settlement of material in the backfilled pit resulted in the 'depressed' mound surface that was described in the 1820s.

The fact that passage graves have been reused during later prehistoric periods has been known since archaeology's infancy. This conclusion was based on discoveries of artefacts that, in addition to representing the inventory of the time when the monuments were built, often reflected activities in the Late Neolithic and Bronze Age. The best-known example is the twin passage grave of Klekkendehøj, which was opened in 1799 (Dehn, Hansen and Kaul 2000, 12-56).

Prehistoric intrusions into and alterations of passage graves

In some cases, indications of intrusions into or alterations of passage graves later in prehistory can be

Figure 6. Section showing the intrusion into the intact Maglehøj passage grave. To the left is the edge of one of the chamber's capstones and below this the flagstone set on edge associated with the secondary closure. Outside these is the back-filled pit from the intrusion (layer 3) (Drawing: L. Holten and M. Nissen).

observed from inside the chamber and passage. But acquiring evidence of an unusual constructional detail not being a part of the original construction requires an intervention into the surrounding mound fill with exposure of the external surfaces of the chamber. This gives the opportunity to observe the construction of the earthen mound, as well as changes in the original stone packing around the exterior of the orthostats and capstones.

One example is the Bigum passage grave. Already on being opened in 1914, it was realised that a large gable stone at one end of the chamber leaned outwards and that the dry-walling was missing on both sides. During a restoration in 1990, a trench was dug into the mound behind the leaning orthostat, and it could be seen that the gable stone had been tilted further outwards so there was access between the upper surface of the gable stone and the capstone (Dehn, Hansen and Kaul 2000, 235-254). The gable stone was subsequently not completely returned to its original position, so the horizontal gap between the gable stone and capstone had been closed with large, rectangular slabs set on edge (Figure 7). It was also apparent that the kerbstone ring had been rebuilt at least twice. During the investigation in 1914, it became evident that the passage lacked capstones. Instead, a Late Bronze Age urn grave stood on one of the orthostats and a stone bearing rock art lay in front of the entrance to the passage. The chamber had two clearly distinct burial layers: The lower layer contained skeletal remains and amber artefacts, while the upper layer had contents that included flint daggers and a bell beaker, indicating that extensive alterations took place in both the Late Neolithic and the Bronze Age.

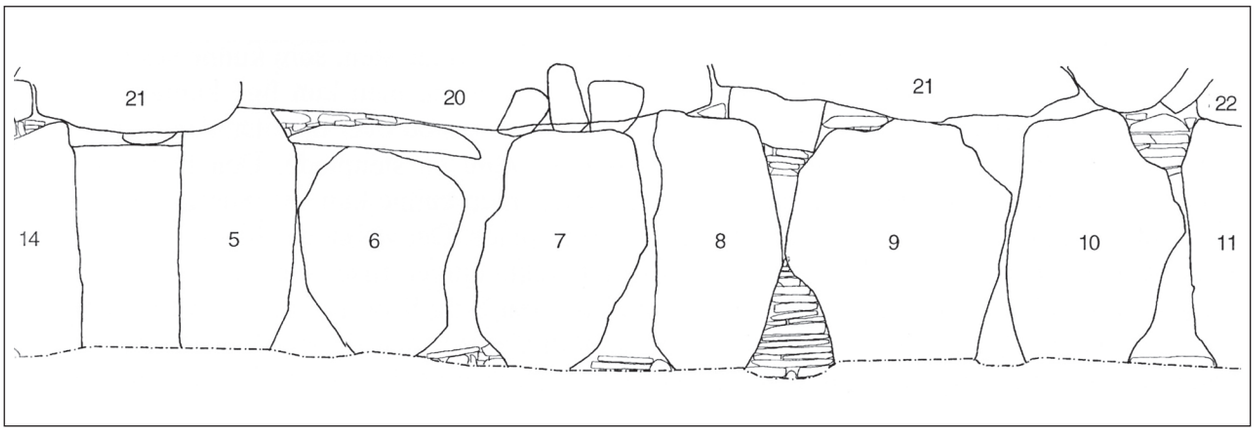

Figure 7. The chamber of the Bigum passage grave was also broken into later in prehistory. On this elevation showing part of the chamber three slabs set on edge cover the gap between orthostat 7 and capstone 20 externally. To the right of this is another slab set on edge between orthostat 8 and 9 (Drawing: T. Dehn).

Vasagård on Bornholm provides a similar example of drastic alterations. A dolmen chamber and a passage grave lie about 20 m apart at each end of a long barrow, 34 m in length. The dolmen chamber was investigated and the passage grave discovered in 1894. Investigation of the latter in 1938 revealed signs of a break-in, as two capstones had partially slipped and the opening between the chamber and the passage had been closed with a stone slab, which stood 40 cm above floor level. In the chamber were traces of a burial from the Late Bronze Age. During a restoration in 2008, it was discovered that capstones and some of the passage's orthostats had been removed. By the outer part of the passage there was a raised horizontal platform laid with slates. A ground-penetrating radar (GPR) scan suggests that this plateau forms part of a terrace which runs around the entire long barrow. The finds include Middle Neolithic pottery and amber beads, as well as half a boat-shaped battle axe from the Battle Axe culture. It is impossible to determine when the passage grave was first subjected to a forced entry, but the long barrow with its terracing can be ascribed to the Bronze Age (Hansen 2014, 48-56).

A third example is evident in the passage grave of Stuehøj near Ølstykke in northern Zealand[2]. This was opened in 1834 by the landowner, who found flint daggers, urns and bronze artefacts, among other things, in the chamber. For many years, the chamber's capstones lay exposed at the base of a large pit, and in 2006 a restoration was initiated. One end of the chamber consisted of a large pile of fieldstones, which was found to represent secondary closure of the chamber after a large orthostat in the gable had been completely removed to give access (Figure 8). A stone socket, together with remains of dry-walling, showed that an orthostat had once stood there (Figure 9).

The stone socket contained flint which had been part of the packing behind the orthostat that was removed from the chamber. The flint had fallen into the gap left when the stone was pulled outwards. The earthen fill that has also fallen into the gap had a high charcoal content, and in the area behind the stone socket there was a 5-10 cm thick layer of charcoal (Figure 9). A likely explanation for this is that fire was used to make the stone brittle so it could more easily be broken into pieces and removed.

Figure 8. The chamber in Stuehøj lacks an orthostat at one gable. This has been replaced by a heap of stones, which includes larger packing stones and a partially toppled orthostat, seen on the lower left of the picture, where the upper part of the stone heap has been removed (Photo: T. Dehn).

Figure 9. The pit dug down to reach the subsequently removed orthostat lay under the stone heap at the gable of Stuehøj's chamber. Remains of dry-walling can just be glimpsed on the left, and the base of the flint packing which has formed part of the structure around the orthostat is visible behind the pit. To the right, this packing is preserved to a greater height. The actual stone socket has a charcoal-rich fill containing a quantity of crushed flint from the packing outside the stone. Immediately above the preserved base of the flint packing is a 5-10-cm-thick charcoal-rich layer. There is therefore much to suggest that fire was used to make the large stone brittle and ease the process of its removal (Photo: T. Dehn).

A similar situation applies in the case of a fourth example – the passage grave Holmshøj near Vojens in southern Jutland.[3] There has been no forced entry into the chamber here but there have been drastic alterations to the passage grave and the entire mound, which was modified and extended on several occasions during the Bronze Age. The chamber was opened in 1884, when it was established that the capstones of the passage were completely

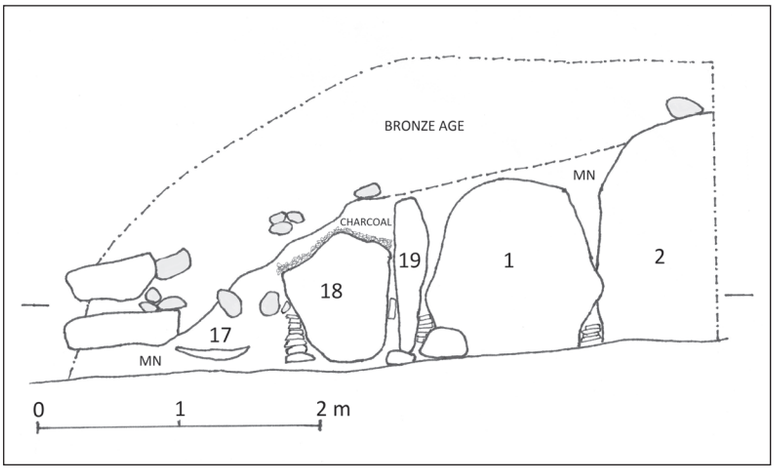

Figure 10. In the Holmshøj passage grave, the outermost part of the passage was reduced in height during alterations to the mound. On this elevation, stones 1, 2 and 19 are still seen in situ, while stone 17 has been removed, although its base remains in a 'rotten' state. The upper part of stone 18 has been hacked off after being rendered brittle by fire. The two horizontal stones on the left form part of the altered kerbstone construction (Drawing: S.I. Hansen and T. Dehn).

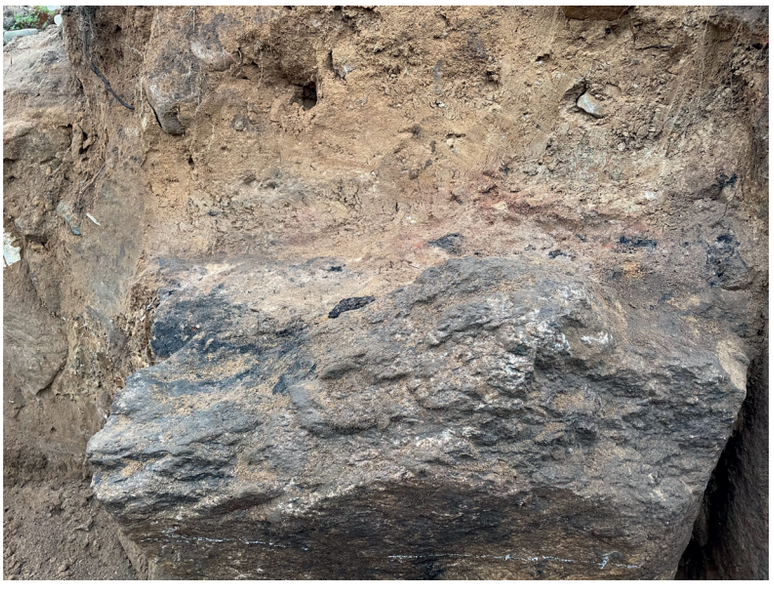

Figure 11. The penultimate orthostat in Holmhøj's passage (no. 18 on Fig. 10) has been reduced in height by hacking away its upper part. Large quantities of charcoal and red-burnt mound fill show that a fire has been lit outside the stone to aid the process (Photo: T. Dehn).

absent. During a restoration in 1887, the orthostats at one side of the passage were broken up to enable a completely new passage to be built which provided better access for visitors. One of the aims of another restoration in 2021 was to remove the latter and, as far as possible, re-establish the original passage. During this process, the preserved side of the passage again became visible (Figure 10).

The outermost part proved to have been reduced in height, presumably so as not to be visible in the surface of the new mound, which at this side was lower than that of the original megalithic mound. This modification had been achieved by removing the capstones over the passage and the outermost orthostat in the passage, as well as by taking the top off the passage's penultimate orthostat. This was achieved by exposing the uppermost part of the stone and then lighting a fire behind it. The fire rendered the stone brittle, thereby making it easier to hack the top off it (Figure 11).

Whether the same actions were undertaken on the opposite side of the passage is not known, as this was removed in 1887. But the kerbstone construction was partially removed on both sides of the entrance to the passage, and partially destroyed, so it too was reduced in height.

As a final example of a possible intrusion into a chamber, mention can be made of the passage grave in the megalithic complex at Tustrup on Djursland. In both 1887 and 1891 this was described as a passage grave in a collapsed state, and it was excavated and restored in 1954 (Eriksen, Dehn and Hansen in press). The orthostat in one gable and a broken capstone together provides a basis for an interpretation that an intrusion into the chamber took place in prehistory. The gable orthostat is tipped outwards and lies at an angle of at least 45 degrees. The capstone is broken into two parts, which lie directly beside the orthostat on the floor of the chamber (Figure 12). It seems

Figure 12. The collapsed and exposed chamber of the Tustrup passage grave in 1954, prior to investigation and restoration. Even back then, the possibility was considered that the collapsed end of the chamber on the left of the picture was caused by an intrusion later in prehistory (after Eriksen, Dehn and Hansen in press).

likely that the breaking of the capstone was caused by the gable orthostat being toppled. Extensive preparatory work was required prior to toppling the large orthostat outwards, as it was necessary to dig a pit measuring *c*.2 x 2 x 2 m from the surface of the mound, part of which had to be cut through some of the solid stone packing which encloses the entire construction.

During the investigation of the passage grave, Funnel Beaker culture artefacts were encountered but there were no finds from other periods, and once again there were no indications of when the mound over the chamber was removed. It is therefore only the collapsed part of the chamber which suggests that a secondary intrusion may have taken place. Similarly, the poor state of preservation of the passage grave prior to restoration excluded the possibility of finding traces of secondary closure.

In addition to these five examples, numerous others can be mentioned where an intrusion and/or alterations must have taken place, but where it is not possible to explain the situation in more detail. A twin passage grave at Årby near Kalundborg completely lacked capstones when it was investigated in 1879. In addition, remains of a Bronze Age burial were found on top of the common orthostat between the two chambers, and in another place a Bronze Age urn stood uppermost in the grave fill. This suggests that at least some of the capstones had been removed in the Bronze Age at the latest (Dehn, Hansen and Kaul 2000, 145-156). When it was opened in 1890, the Nissehøj passage grave near Vellerup in Zealand was found to contain an oak coffin burial from the Bronze Age. During a restoration in 1992 it could be established that the outer part of the passage had been altered, presumably to make it possible for the oak coffin to be manoeuvred into the chamber. The passage was then closed with a stone slab, which stood upright in a Late Neolithic burial layer (Dehn, Hansen and Kaul 2000, fig. 5.26).

Common to Maglehøj and the other examples of forced entry into and alterations of passage graves is that these activities cannot be securely dated. The only possible exceptions are Stuehøj and Holmshøj, where charcoal can be dated, but this has not yet been undertaken. Nevertheless, the artefacts found in the chambers provide some indications of likely dates, typically in the form of information from Late Neolithic flint daggers and Bronze Age artefacts in the chambers. Rock art on the stones is also suggestive of activities in the Bronze Age – at least when the motifs take the form of figures, as seen on the stone found in front of the entrance to the passage and included in the new ring of kerbstones around the Bigum passage grave (Dehn, Hansen and Kaul 2000, figs. 14.4 and 14.6). Cupmarks, on the other hand, commonly occur on the capstones and orthostats of both dolmens and passage graves. In some cases, this is undoubtedly because the surfaces of these stones were accessible in the Bronze Age, but it also seems likely that some of them were carved already in the Middle Neolithic. Two stones bearing cupmarks were found in a Middle Neolithic context in one of Vasagård's palisade ditches, but an

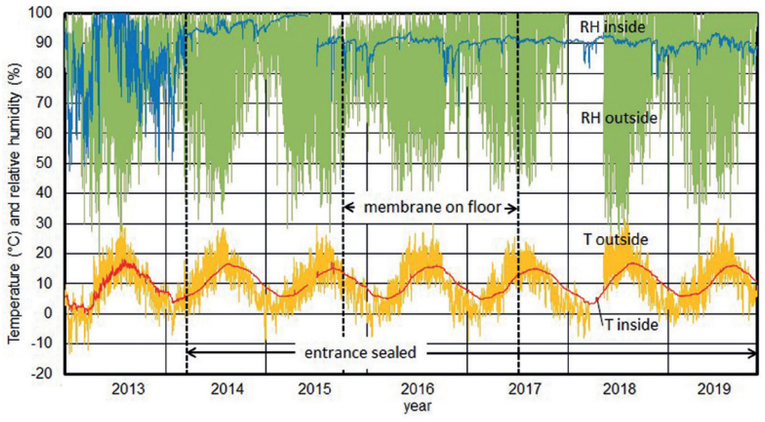

Figure 13. Measurements of temperature and relative humidity inside and outside the Maglehøj chamber in the period 2013-19.

earlier date is also possibly (Iversen, Thorsen and Andresen 2022, 163). Moreover, in the presentation of a major project encompassing an evaluation of dolmens in northern Europe, it is proposed that the stones which were included in megalithic graves were selected and carved with cupmarks before they were incorporated into the monument (Cummings and Richards 2021, 63-92).

The passage graves' birch bark and its preservation

Following the rediscovery of the occurrence of birch bark in Maglehøj, increased awareness of this phenomenon has resulted in the finding of this material in several passage graves. In 2006, eight occurrences were known (Dehn and Hansen 2006), and since then the presence of birch bark has been confirmed in a further four passage graves, two of which lie in Scania, Sweden[4] (Hansen 2016, 104). The birch bark between the dry-walling slabs is normally poorly preserved and, in some cases, only recognisable as small fragments. Maglehøj is therefore the only known passage grave to date where the bark is preserved to any greater extent so that it is clearly visible and illustrates how this material was generally used.

A common feature of the passage graves with preserved birch bark is that the chambers were partially or completely earth-free until they were opened in modern times. A further characteristic is that behind the dry-walling with birch bark there is a solid packing of crushed flint. This held the rear of the dry-walling free of the earth of the mound fill and permitted a certain degree of desiccation.

Preservation conditions for birch bark

In the period 2013-19, the Danish National Museum's Department for Environmental Archaeology and Materials Science undertook an investigation of the preservation conditions for birch bark in the Maglehøj passage grave (Larsen et al. 2017). There was a suspicion that the bark was undergoing degradation, even though it was judged to be reasonably intact in 1995 The aim was to clarify how the reopening of the chamber in 1823 had influenced the internal climate. There was a particular awareness that condensation, which was observed on both orthostats and capstones, could be damaging to the birch bark. In addition, samples of the birch bark were taken to be investigated for signs of decay.

During the first year of the investigation the passage leading into the chamber was open, while in the subsequent 5 years it was closed with a sealed door. Temperature and relative humidity were measured both inside and out with the aid of electronic sensors attached to a central data logger (Figure 13). The measurements showed that the internal temperature follows the average external temperature with a delay of about a month. The annual fluctuations in temperature are damped inside the chamber so the maximum lies some degrees lower and the minimum some degrees higher than the corresponding averages for the external temperature. This is due to the thermal inertia constituted by both the stones and earthen fill, as well as the earth below the floor. There is only a marginal difference in the fluctuation from summer to winter between the open and the closed passage. The thermal stability is far from adequate to level out annual variations

Figure 14. The Maglehøj chamber seen looking north, with a damp-proof membrane on the floor. The internal climate sensors can be seen on the right (Photo: R. Fortuna, Danish National Museum).

in temperature, regardless of whether the chamber is open or not.

The closing of the chamber had a much greater influence on air humidity than on temperature. In the open chamber, air humidity varies between 50 % and 100 % RH according to the season and external climate. There are frequent episodes with condensation on the internal surfaces in the period between April and September. This is because the external air during this period is warmer than the chamber and contains a relatively large amount of water vapour. When this warm, damp air meets the cold surface of the stones, the water vapour condenses. In the closed chamber, the relative humidity is high and constant, around 90 % RH all-year round. Even so, condensation is a rare occurrence. This is because the temperature of the air is almost the same as the surface temperature of the stones. Even though the relative air humidity is high, the dewpoint is rarely exceeded. The closed situation has presumably prevailed during most of the monument's existence up until the opening of the chamber two centuries ago. There has therefore been a stable, damp climate *without condensation* for much longer than a variable climate with alternating periods of desiccation and condensation (Figure 14).

In addition to the climate measurements undertaken in the actual chamber, the moisture content of the earth in the floor below the chamber and in the fill above it was also measured. The earth was generally damp down to a depth of about a metre all-year round, but in the open chamber the surface dried out in winter, when the relative air humidity was low. This is due to evaporation from the upper layer of the floor into the air. As the climate was very wet during the first year after the chamber was closed, the floor was experimentally covered with a damp-proof membrane. Subsequently, the air humidity stabilised at 90 % RH, which apparently confirmed the influence of the damp floor on the climate in the chamber. But the membrane was removed for the final 2 years, without any noticeable effect on air humidity. Evaporation from the damp earthen layer of the floor is therefore of less significance for condensation than first assumed.

The earthen fill over the chamber was saturated by moisture during winter and dried out in summer. The precipitation was evenly distributed through the year, so the earth's moisture content was essentially determined by the evaporation. There was no connection between the moisture content of the earthen fill and periods with condensation inside the chamber. The influx of moisture from the earthen fill into the chamber is therefore judged to be insignificant. It is assumed that the original clay packing over the chamber is intact. There is consequently no need to establish a new moisture barrier over the chamber.

The natural air change was measured through two 3-week periods in February and August 2016 in collaboration with the Danish Building Research Institute (SBI) by the perfluorocarbon tracer method (PFT). The closed chamber had an average air change of 0.34 h^{-1} in February and 0.16 h^{-1} in August. This means that between 16 and 34 % of

Figure 15. The folded birch bark between the sandstone slabs in the dry-walling in Maglehøj (Photo: L. Aa. Jensen, Danish National Museum).

the air in the chamber was renewed each hour. This is a surprisingly high rate, which corresponds to a normal leaky house with windows and doors. In June 2016, an attempt was made to localise leaks in the chamber with the aid of cold smoke. A ventilator was installed in the door to give slight positive pressure. A small amount of smoke escaped through the passage over the door, but no smoke was observed through mouseholes or other parts of the mound.

It is therefore assumed that the relatively large air change takes place evenly distributed through the porous earth and the flint packing around the outer surface of the orthostats. From here, the air penetrates through the cracks between the individual sandstone slabs in the dry-walling as well as other gaps between the orthostats. In this way, the dry-walling forms part of a rather effective ventilation system, which is driven by small pressure differences caused by wind or temperature gradients. If all the gaps in the dry-walling were sealed with birch bark, the air change would probably be significantly lower. We cannot know whether this effect was intended by chamber's builders.

Due to the high natural air change, it is unlikely that the chamber has been deficient in atmospheric oxygen (O_2). But oxygen also occurs in the form of ozone (O_3), which is much more reactive and is therefore a significantly more powerful degradation factor. The ozone concentration in the closed chamber was investigated by several independent methods in spring 2016. The measurements demonstrated unanimously that the ozone level in the closed chamber is virtually zero, even though the natural air change is quite considerable. During the air's passage through the earthen mantle, the ozone reacts with organic components and a conversion takes place. Consequently, the earth functions as an effective ozone filter, and probably also as a filter for other reactive components in the air.

The influx of ozone into the chamber was then investigated with an open passage. Over the course of two sunny days in June 2016, the ozone level was measured inside and outside the chamber through a period of 48 hours. The ozone level in the middle of the open chamber was 8 ppb (average) but varied between day and night (<1-15 ppb). But the ratio of inside to outside concentration was, however, largely a constant 0.25. Spot measurements undertaken directly in front of the dry-walling showed a slightly lower inside to outside ratio of *c*.0.2. In the open chamber there is, accordingly, free access for ozone, with the birch bark also being exposed. In the two centuries that have elapsed since the Maglehøj chamber was reopened, the birch bark has been influenced by ozone corresponding to a millennium of open air. This has probably contributed to degradation of the bark by oxidation (Figure 15).

Several studies have been undertaken of the degradation and conservation of birch bark (Orsini et al. 2015). There is general agreement that the material is exposed to 'natural ageing', resulting in it becoming brittle and stiff. Natural ageing is due to oxidation and hydrolysis, where-

Figure 16. Maglehøj seen from the south with the entrance to the right. The external climate sensors can be seen in the centre (Photo: L. Aa. Jensen, Danish National Museum).

by the material's components are broken down by chemical reactions with oxygen and water. The cell structure of birch bark differs substantially from that of an ordinary wood cell, both physically and chemically. In chemical terms, suberin rather than cellulose constitutes the greatest component of the cell wall (*c.*45 %), and it is suberin that gives birch bark its strength and flexibility. The second largest component is betulin (*c.*34 %), which is antiseptic and hydrophobic and gives birch bark its pale appearance. Analyses of the birch bark from Maglehøj have confirmed that the bark's components are affected by chemical changes. Conversely, there are no indications of microbial degradation of the bark's structure.

Birch bark absorbs only *c.*5 % water at 100 % RH, which is much less than birch wood. On drying out, the various layers of the bark are affected by varying tensile stress, causing an unrestrained piece of bark to curl up. Birch bark preserves best in a stable, damp climate.

Conclusion

The investigation of Maglehøj is an example of how a careful review of an archival source can be of significant importance for the outcome of an archaeological investigation in a well-preserved monument. Pastor Holm's description of the passage grave is of exceptionally high quality, but it has also proved invaluable in other projects to closely read older descriptions as part of the preparation for an investigation. Maglehøj is also an example that drastic changes to the construction of both chamber and passage may have been made during later prehistoric use of passage graves. This observation has been of great importance for the analysis of other passage graves.

Based on the results of the investigations of the preservation conditions for birch bark, it is recommended that a permanent, air-tight closure of the door is established to stabilise the internal climate and keep the chamber free of ozone. Access for visitors is already hindered by a locked airtight metal door, so accessibility will not be further impeded. There are many other well-preserved burial chambers without birch bark which can better tolerate the wear that people and animals inflict on the remains of the 5000-year-old bark (Figure 16).

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Notes

1) Sulkendrup Mølle, reg.no. 090617-9; report of 2015 in slks.dk/sites-and-monuments.
2) Stuehøj, reg.no. 010607-53, report of 2006 in slks.dk/sites-and-monuments.
3) Holmshøj, reg.no. 200210-157, report of 2021 in slks.dk/sites-and-monuments.
4) Møllehøj, reg.no. 010604-33, Øm passage grave, reg.no. 020402-13, as well as Örenäs and Ljunghög in Scania, Sweden.

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